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Testing of Copper Fungicides for Control of Tomato Blight in Southwest Virginia

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BLACKSBURG, MONTGOMERY COUNTY, VIRGINIA

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TESTING OF COPPER FUNGICIDES FOR CONTROL OF TOMATO BLIGHT IN SOUTHWEST VIRGINIA[1]

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Introduction

Reports from various sections of the United States indicate that the yield of tomatoes is greatly reduced every year by certain foliage diseases. The diseases, which are frequently referred to as "blight," include Septoria leaf spot (*Septoria lycopersici*), early blight (*Alternaria solani*), late blight (*Phytophthora infestans*), and Stemphylium leaf spot (*Stemphylium solani*). The degree of injury is influenced by the climatic conditions of the season, but reports indicate that the losses from blight have been large during the last few years (1, 2, 5, 7, 10, 11). Blight was especially severe in 1942. According to McNew (11), late blight (*Phytophthora infestans*) reached epiphytotic proportions in the State of New York in 1942, while in New Jersey (7), early blight, Septoria leaf spot, and Stemphylium blight caused large losses.

In Virginia, tomato blight is usually of minor importance in the Eastern Shore area (3), but in the Piedmont and Southwest sections of the State it is prevalent each year; and during seasons favorable for its development, may reduce the yield of marketable fruit by 50 to 75 percent. Tomatoes in home gardens are especially hard hit by blight and the secondary injuries which follow; namely, soft rot (*Erwinia carotovora* and *Erwinia aroideae*) and sun scald.

The blight in Southwest Virginia appears to be due primarily to *Alternaria solani*, but in some cases the infections by this organism are apparently initiated by *Septoria lycopersici* and *Phytophthora infestans*. *Phytophthora* lesions in their later stages become covered with Alternaria spores, thus making it difficult to evaluate the importance of each fungus. Phytophthora lesions (probably *P. infestans*) on the fruit are of common occurrence and during some seasons a rather large percentage of the fruits are infected by this fungus.

Fungicides for combating tomato blight in the field have not been recommended for general use, although considerable data have been published which show that the yield of marketable fruits can be greatly increased by fungicidal applications. McNew (11) has shown that Bordeaux mixture and certain fixed copper preparations were highly effective in controlling Phytophthora fruit rot. In his tests, infection was limited almost entirely to untreated plants. Fromme (6) in experiments conducted in 1918-1919, was able to increase the yields of sound fruit about 70 percent by applying resin fish oil soap Bordeaux mixture. In his tests copper-lime dust also proved to be very effective in the control of Phytophthora fruit rot. In experiments conducted in Eastern Virginia, Davis and others (4) showed that spraying with Bordeaux or dusting with copper-lime dust increased the yield of tomatoes. The practicability of applying fungicides to tomatoes in the field on the commercial plantings in Eastern Virginia, however, remains in doubt. Nugent (13) found in recent tests conducted in that area that the application of fungicides to tomatoes did not give a significant increase in yield. Cook and Nugent (3) stated that observations over a period of years indicated

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that leaf spots were not of economic importance more often than about 1 year in 5 in Eastern Virginia. Considering the low margin of profit in the tomato crop, it would not be economical to spray every year in order to obtain protection during the occasional years when leaf spots are destructive. In other sections of the State, however, the situation is entirely different. The disease attacks are moderate to severe nearly every year and the fruit is grown largely for home consumption or the fresh fruit market. Home gardeners in Southwest Virginia are extremely desirous of employing measures that are effective in the control of tomato diseases.

The experiments discussed herein were conducted at Blacksburg, Virginia, during the years 1939 to 1942 inclusive. The 1939 experiment was only preliminary. The 1940 experiment was more extensive, but an early killing frost terminated the test before much of the fruit of the later varieties had ripened. Since the results obtained in these tests have been only briefly reported elsewhere (8, 9) they will be discussed further here. The data presented in this bulletin, however, have come primarily from experiments conducted in 1941 and 1942.

Materials and Methods

The plot layout was a split-plot design in which three varieties and six treatments were used. The varieties were Earliana (early), Pritchard (medium early), and Marglobe (late). Since these varieties differ so much in date of maturity and yielding ability, the data on each variety have been analyzed separately. Also in the statistical analyses the data for the two years (1941, 1942) have been handled separately, because 1941 was extremely dry in late summer and conditions were unfavorable for disease development, while in 1942 heavy rains occurred and the environmental conditions were quite favorable for disease development. The same area of ground was used for the experiment each year. It was first planted to tomatoes in 1940. Previous to that date it had grown various field crops.

The field was approximately 66 feet wide by 450 feet long. It was divided lengthwise into three sections for the three varieties, then crosswise for treatment plots. The individual plot consisted of 1/121 acre and was planted to 30 plants in rows 4 feet apart with the plants 3 feet apart in the row. The treatments were replicated 4 times. The plants were grown in the greenhouse and transplanted to the field about June 1. A 4-12-4 fertilizer was applied just before setting at the rate of 600 pounds per acre. A side application of nitrate of soda (about 50 pounds per acre) was made after the first fruits were set. The fungicidal applications were started on July 1 and repeated at about 10-day intervals. In 1941 the July 1 application was omitted on Pritchard and Marglobe since their growth was not as far advanced as Earliana. The last application that year was made on August 20, making a total of 6 applications on Earliana and 5 on the other varieties. In 1942 all varieties received 5 applications, the last one being made August 15. The early sprays were applied with a small motor-driven sprayer of the wheelbarrow type. A pressure of about 150 pounds was maintained. The last two spray applications in 1941 and the last one in 1942 were made with a large power sprayer, operated at a pressure of about 225 pounds. The sprays were applied from a single nozzle on a short rod. The plants were sprayed thoroughly but not drenched.

The dusts were applied with a motor-driven duster (Messinger). This duster was made for row dusting, being equipped with four dust outlets, but for this

test, three of the openings were closed and a long flexible tube connected to the fourth. A man held this tube and applied the dust to the plants from all sides. In this way the foliage was uniformly covered with a minimum amount of dust. In order to prevent drifting of the dust on to the adjacent plot a heavy cloth was spread over the border row while the dust was being applied.

The fruits were harvested at frequent intervals and graded into four grades: No. 1, No. 2, culls, and rots. Each grade was then weighed and recorded as pounds per plot. The specifications for U. S. grades were followed except for color. The fruits were sold for table use and it was necessary to pick them when they were only partially colored; otherwise the No. 1 and No. 2 grades met U. S. specifications for canning stock. The weights of rotted fruits in 1942 do not represent all the fruits that should have been in this class, since many fruits destroyed by soft rot were mashed and lost in picking. In 1941 soft rot was of minor importance.

The materials employed in these studies were tribasic copper sulphate and cuprous oxide, each used in the form of a dust and spray, and Bordeaux mixture spray. The tribasic copper sulfate dust used was mixed especially for our test by the Tennessee Copper Company. It contained 12½ pounds of tribasic copper sulfate (53.0 percent metallic copper), 20 pounds of wheat flour, and 67½ pounds of clay. The cuprous oxide used in the preparation of the copper oxide dust was manufactured by Rohm and Haas Company, but the dust mixture was prepared by Southern States Cooperative especially for our use. Red cuprous oxide was used in 1941 and the dust mixture contained 5.1 percent metallic copper; whereas in 1942, the yellow form was used and the metallic copper content of the dust mixture was reduced to 4.1 percent. The copper oxide dust used in the first three applications in both seasons contained, in addition to the copper, 20 percent calcium arsenate. The subsequent applications, however, contained no calcium arsenate.

The copper oxide for the spray was manufactured by Rohm and Haas Company and sold under the trade name of "Yellow Cuprocide." It contained 83 percent metallic copper and was used at the rate of 1½ pounds to 100 gallons of water.

The tribasic copper sulfate used as a spray was manufactured by the Tennessee Copper Company and it analyzed 53.9 percent metallic copper. The spray mixture contained 4 pounds tribasic copper sulfate, 1 pound soybean flour, and 100 gallons water. The soybean flour was made into a thin paste by stirring with a small amount of water, after which it was added to the spray tank.

The Bordeaux mixture used in these tests was a standard 4-5-50 Bordeaux, prepared from copper sulfate and hydrated lime.

Results of 1940 Test

As mentioned above the yield records on Pritchard and Marglobe were incomplete due to an early frost. The data obtained on Earliana and the incomplete data on Pritchard and Marglobe, however, clearly showed that the yields of tomatoes could be greatly increased by the use of fungicides. The greatest increases in the short season of 1940 were with tribasic copper sulfate and copper oxide, both as a spray and as a dust. The yield of the plots sprayed with Bordeaux were considerably smaller than those from the plots treated with the other fungicides. The Bordeaux sprayed plots were found not to differ significantly from the unsprayed check. On Earliana the average yield was slightly higher than that of the check, but on Pritchard and Marglobe it was lower than the

checks. The calculated per-acre yields of ripe fruit for the different treatments on Earliana were as follows:

	tons [1]
Copper oxide spray	14.14
Copper oxide dust	14.77
Tribasic copper sulfate spray	12.35
Tribasic copper sulfate dust	14.54
Bordeaux spray	9.96
Check	9.19

Results of 1941 Test

The yield data obtained on the 1941 experiment are given in table 1. The yields at the several pickings have been grouped so as to give the total yields for 10-day periods, beginning August 8. It will be noted that no fruits were picked from the Pritchard variety during the first 10-day period nor from the Marglobe variety during the first two 10-day periods. This means that Pritchard was 10 days later than Earliana, and that Marglobe was 20 days later than Earliana. Also in 1941 there was a significant difference in yields of the three varieties. The total yield of No. 1 and No. 2 fruits from all treatments was 6,469 pounds for Earliana, 5,264 pounds for Pritchard, and 4,494 pounds for Marglobe. A study of the weather records given in Table 3 will reveal the reason for the difference in yield in favor of the earlier maturing varieties. There was an abundance of rainfall in June and July, but in August and September it was very dry. Earliana, having made all of its initial growth in the favorable season of June and July, ripened an abundance of fruit in the dry month of August. On the other hand, the growth of the later maturing varieties was not sufficiently advanced to escape damage from the dry weather in August and September. Marglobe, the latest of the three varieties was affected most by the drouth. Because of the influence of this seasonal factor, a comparison between varieties is not justified, although there may have been some varietal differences in susceptibility to blight.

The yield data from the various treatments were analyzed statistically. A summary of this analysis is given in Table 5. The yield of the Earliana and Pritchard plots receiving fungicidal applications was significantly better (1 percent level) than that of the untreated check plots, but the yield of the treated Marglobe plots was just short of being significantly better than the untreated check plots. The yields of marketable fruit of all the sprayed and dusted plots were about the same and the statistical analysis showed that there was no difference between fungicidal treatments when yields alone were considered. But, when the influence of the treatment on rate of ripening (pickings x treatments) was considered, there was found to be a significant difference between the Bordeaux and the other fungicidal treatments. This was true for all three varieties in 1941. A comparison of the picking trend is graphically illustrated by the regression lines in Figure 3. The influence of Bordeaux on the picking yields appears to be greater for Marglobe than for Pritchard and Earliana. Since the slope of these regression lines is influenced by the total yield as well as by the rate of ripening, the differences in the slope of the lines cannot be attributed to a difference in the rate of ripening unless there is an insignificant variation

[1] The yields given were calculated from the average of 4 plots of 25 plants each. In 1940 the fruits were not graded; therefore, these yields include some fruits that should have been classed as culls.

in the yields of the plots concerned. Therefore, the regression lines for the plots of Earliana and Pritchard that received fungicidal applications cannot be compared with those of the untreated plots because the means of these plots vary significantly. There was no significant difference in the yield of the treated and untreated plots of Marglobe; therefore, the great difference in the slope of the

Table 1.—Yield of tomatoes in 1941 from plots approximately 1/30 acre [1]

Treatment	Harvest dates	Earliana				Pritchard				Marglobe			
		No. 1	No. 2	Culls	Rots	No. 1	No. 2	Culls	Rots	No. 1	No. 2	Culls	Rots
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Tribasic dust	8/2–8/11	16.8	8.8	6.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/12–8/21	50.3	39.5	22.0	12.3	6.3	3.8	2.0	0.8	0.0	0.0	0.0	0.0
	8/22–8/31	201.8	106.5	52.5	20.8	64.5	19.0	12.0	1.8	17.0	12.8	2.8	1.9
	9/1–9/10	284.3	197.3	74.5	18.0	294.3	79.8	24.5	9.8	150.2	35.0	5.2	5.9
	9/11–9/20	102.0	77.5	53.3	9.0	268.3	113.5	43.3	8.3	253.3	92.4	21.8	4.0
	9/21–9/30	20.3	24.5	33.8	6.3	50.5	31.5	60.5	4.5	97.0	58.5	58.5	6.3
	10/1–10/10	2.0	4.3	12.3	2.5	5.3	13.3	62.5	5.5	25.3	45.3	67.2	5.3
Total		677.5	458.4	254.4	73.4	689.2	260.9	204.8	30.7	542.8	244.0	155.5	23.4
Copper oxide dust	8/2–8/11	15.8	8.8	7.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/12–8/21	64.5	37.5	31.3	11.5	3.3	3.3	1.5	0.8	0.0	0.0	0.0	0.0
	8/22–8/31	177.5	121.5	64.0	22.3	67.2	18.1	15.1	4.9	16.3	16.1	4.6	1.2
	9/3–9/10	301.0	144.3	96.8	13.8	261.0	75.3	21.6	10.5	135.2	38.3	7.7	5.4
	9/11–9/20	114.0	68.3	79.5	8.3	266.1	138.2	50.9	5.3	255.2	114.3	29.7	6.7
	9/21–9/30	27.3	30.0	32.3	3.5	36.6	29.3	50.9	3.5	77.7	42.5	56.9	5.6
	10/1–10/10	1.5	3.3	4.3	2.0	4.5	10.3	43.5	4.0	14.5	22.4	52.4	4.8
Total		701.6	413.7	315.2	65.2	638.7	274.5	183.5	29.0	498.9	233.6	151.3	23.7
Copper oxide spray	8/2–8/11	19.5	10.8	6.3	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/12–8/21	71.8	37.5	25.0	7.3	5.5	3.5	2.5	1.8	0.0	0.0	0.0	0.0
	8/22–8/31	216.0	111.5	55.0	15.5	58.8	21.3	11.8	2.3	16.1	16.5	5.1	2.5
	9/3–9/10	322.8	148.3	69.5	13.8	252.3	53.8	18.0	10.3	120.3	34.0	4.7	5.5
	9/11–9/20	119.0	67.8	48.5	10.5	229.3	117.5	35.0	6.8	255.6	99.4	25.3	7.6
	9/21–9/30	60.8	32.0	41.5	7.0	67.5	49.5	58.0	3.3	103.9	62.1	55.4	4.2
	10/1–10/10	6.0	4.0	10.0	3.3	12.0	20.0	64.5	6.8	17.3	32.0	54.0	4.1
Total		815.9	411.9	255.8	61.2	625.4	265.6	189.8	31.3	513.2	244.0	144.5	23.9
Check	8/2–8/11	17.6	9.8	8.3	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/12–8/21	58.9	51.6	57.7	14.3	7.3	4.8	2.3	1.5	0.0	0.0	0.0	0.0
	8/22–8/31	169.3	123.4	79.2	24.1	87.3	28.0	30.3	4.0	34.0	18.2	11.5	3.7
	9/3–9/10	118.4	85.0	86.2	21.4	207.0	89.5	48.5	16.8	158.0	61.9	22.7	8.3
	9/11–9/20	24.2	21.3	65.8	13.3	124.0	85.3	70.8	14.3	179.3	105.8	61.1	8.3
	9/21–9/30	0.3	1.8	8.8	2.3	4.3	5.5	56.3	4.0	31.1	26.9	62.1	3.1
	10/1–10/10	0	0.5	1.8	1.5	0.3	2.5	24.5	5.5	4.7	13.8	40.1	4.1
Total		388.7	293.4	307.8	82.7	430.2	215.6	232.7	46.1	407.1	226.6	197.5	27.5
Tribasic spray	8/2–8/11	21.9	9.8	5.8	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/12–8/21	83.2	54.8	34.5	7.8	4.8	3.3	1.3	0.3	0.0	0.0	0.0	0.0
	8/22–8/31	198.6	104.3	60.1	18.3	58.3	22.0	14.5	2.3	21.8	18.1	5.9	3.8
	9/3–9/10	328.4	175.2	102.2	13.1	287.5	66.3	23.8	9.5	195.7	46.6	7.3	9.2
	9/11–9/20	119.9	58.6	58.9	7.8	272.3	115.8	46.5	4.3	227.9	96.1	33.0	7.6
	9/21–9/30	42.2	29.7	45.1	7.0	45.5	36.5	56.3	4.5	81.0	53.8	65.4	1.7
	10/1–10/10	3.3	2.8	12.6	4.8	11.0	21.5	84.5	6.8	24.4	43.3	81.6	7.0
Total		797.5	435.2	319.2	66.1	679.4	265.4	226.9	27.7	550.8	257.9	193.2	29.3
Bordeaux	8/2–8/11	22.8	6.3	6.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/12–8/21	59.8	44.8	33.3	8.0	4.5	2.0	1.8	1.0	0.0	0.0	0.0	0.0
	8/22–8/31	177.5	84.3	67.8	16.3	54.0	21.3	15.0	1.5	17.7	14.4	6.2	1.4
	9/3–9/10	260.5	154.0	76.8	16.0	260.3	61.8	18.5	13.0	125.9	36.3	8.7	4.5
	9/11–9/20	86.5	64.8	63.5	11.5	175.8	122.3	30.3	6.0	169.1	62.6	25.2	5.8
	9/21–9/30	58.0	39.5	52.0	7.3	97.0	65.0	70.5	5.5	148.9	64.4	56.3	6.7
	10/1–10/10	10.8	10.5	16.8	4.0	20.8	33.8	82.3	6.3	67.0	69.2	103.5	10.0
Total		675.9	404.2	316.2	66.4	612.4	306.2	218.4	33.3	528.6	246.9	199.9	28.4

[1] Yields given are from four 1/121-acre plots of 30 plants each which is equivalent to approximately 1/30 acre.

regression lines for the treated and untreated plots of Marglobe is largely due to the difference in the rate of ripening.

In summarizing, it is quite clear, as shown by the regression lines and by the test of significance of the interaction pickings x treatments, that Bordeaux retards the harvest to a much greater extent than the other fungicides.

The yields from the treated and untreated plots were also calculated on a percentage basis as given in Table 2. The percentage of No. 1 fruits was greatly increased by all the fungicidal treatments. For Earliana, only 36.2 percent of the fruits from the check plots rated the No. 1 grade, while 52.8 percent of those from the copper-oxide-sprayed plot rated this grade. For Pritchard and Marglobe, there was also an increase in No. 1 fruits from the treated plots, but the increase was slightly smaller than that of Earliana. The statistical analysis of the percentage of No. 1 fruits is summarized in Table 6. On the Earliana variety the percentage of No. 1 fruits for the two sprays (copper oxide and tribasic copper sulfate) was higher (5 percent level) than that for the same materials when used as dusts. There was no difference, however, between the two materials when used as dusts nor between them when used as sprays; nor was there any difference between the average yield from copper oxide and tribasic copper sulfate, either as dust or spray, and that from Bordeaux spray. The average percentage of No. 1 fruits from the plots receiving fungicides was significantly higher than that from the untreated plots.

Table 2.—Percentage of fruit in the four grades from plots treated with different fungicides

Treatment	Earliana				Pritchard				Marglobe			
	No. 1	No. 2	Culls	Rots	No. 1	No. 2	Culls	Rots	No. 1	No. 2	Culls	Rots
1941	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Tribasic dust	46.3	31.3	17.4	5.0	58.1	22.0	17.3	2.6	56.2	25.3	16.1	2.4
Cu_2O dust	46.9	27.6	21.1	4.3	56.7	24.4	16.4	2.6	55.0	25.7	16.6	2.6
Cu_2O spray	52.8	26.6	16.5	3.9	56.2	23.8	17.1	2.8	55.4	26.4	15.6	2.6
Check	36.2	27.4	28.7	7.7	46.5	23.3	25.2	5.0	47.4	26.4	23.0	3.2
Tribasic spray	49.3	26.9	19.7	4.1	56.6	22.1	18.9	2.3	53.4	25.0	18.7	2.8
Bordeaux	46.2	27.6	21.6	4.5	52.3	26.2	18.7	2.8	52.7	24.6	19.9	2.8
1942												
Tribasic dust	8.8	45.4	37.7	8.1	43.0	35.7	19.1	2.1	48.0	34.5	14.9	2.6
Cu_2O dust	10.0	42.1	39.2	8.8	43.7	35.8	18.0	2.5	52.8	31.2	13.6	2.4
Cu_2O spray	9.1	41.2	39.3	10.4	39.8	37.9	18.3	3.9	51.4	32.0	13.4	3.2
Check	6.3	32.8	45.7	15.2	18.0	41.9	33.3	6.7	19.5	44.8	29.7	6.0
Tribasic spray	10.6	43.6	38.2	7.6	42.0	38.6	17.1	2.3	46.9	34.3	16.2	2.6
Bordeaux	12.0	45.4	35.5	7.1	51.8	30.5	14.7	2.9	57.2	26.7	13.5	2.6

Table 3.—The monthly precipitation at Blacksburg, Va. during the summer of 1941 and 1942. From the U. S. Weather Bureau records

Month	Precipitation in inches	
	1941	1942
June	6.94	5.66
July	6.08	2.68
August	1.29	4.77
September	1.49	3.59

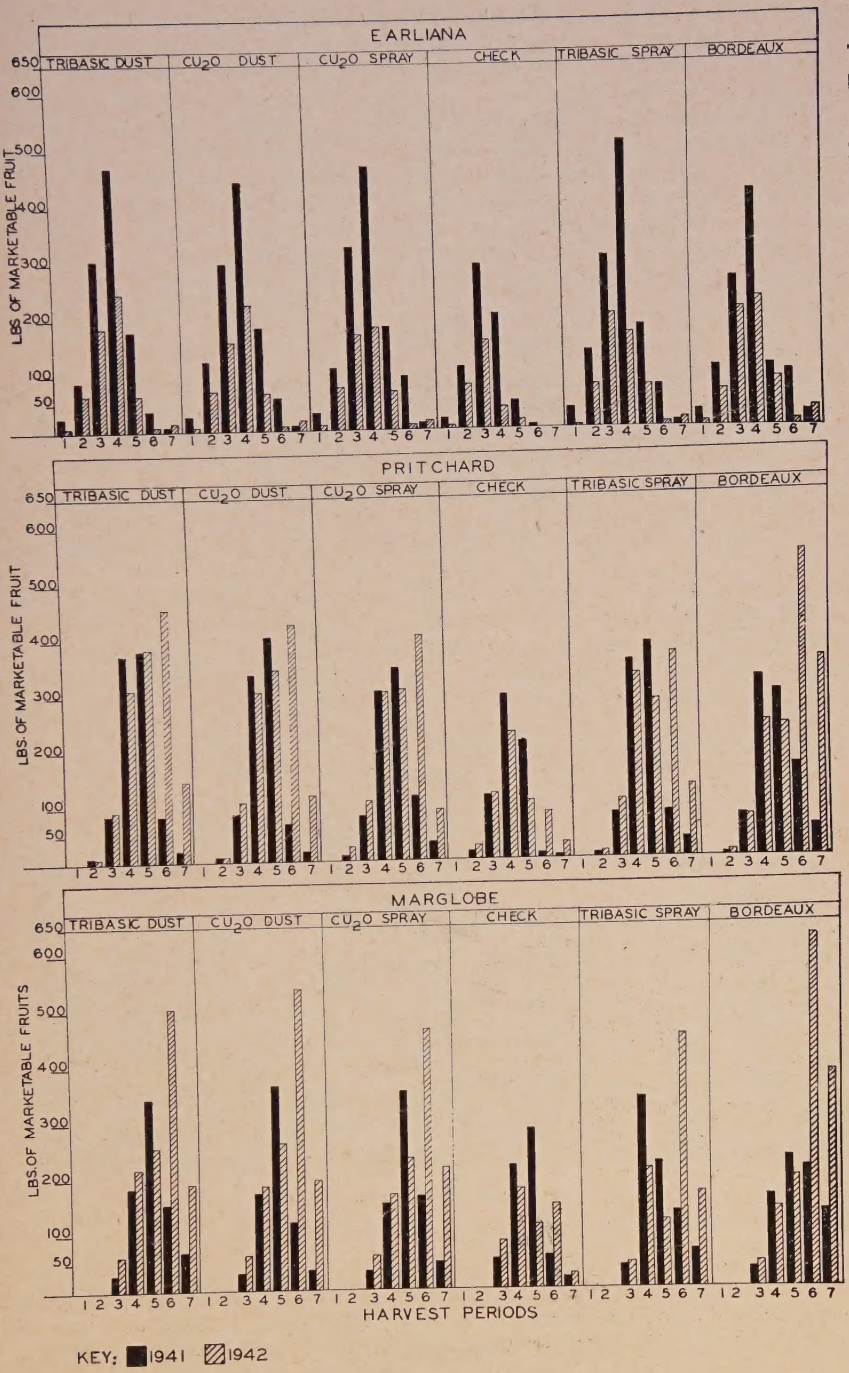

Figure 1.—Pounds of marketable fruit harvested from 1/30-acre plots treated with the different fungicides. Each harvest period represents a 10-day interval and includes all the fruit picked during that period.

On Pritchard and Marglobe, there was no significant difference in the percentage of No. 1 fruits from the different fungicides, the percentage being about the same for each treatment. The percentage of No. 1 fruits from the plots receiving fungicidal applications, however, was higher (5 percent level) than that from the untreated plots.

All the fungicides used in 1941 gave a significant increase in yield on Earliana and Pritchard, but not on Marglobe, which was severely injured by the drouth in late summer. No one fungicide proved to be better than another when total yields of marketable fruits were compared. In every case, however, the picking yields from the Bordeaux treatment were smaller than those from the other treatments in the first part of the season and larger in the latter part of the season. The yield data are graphically illustrated in Figures 1 and 2.

Results of 1942 Test

Leaf spot development in 1942 was very abundant, especially on Earliana. As a result, the yields for Earliana were quite low; but, because of more favorable rainfall during the latter part of the season, the yields for Pritchard and Marglobe were considerably above those of the previous year. The yields for the various treatments are tabulated in Table 4. As in the data for 1941, each amount represents the total yield over a 10-day interval, beginning with the first picking on July 27. The statistical analysis of the yield data is summarized in Table 5.

None of the fungicides used gave effective control of blight on Earliana and, as a result, very low yields were obtained on this variety. Disease control on Pritchard and Marglobe was very satisfactory in spite of the rainy season. A killing frost on September 29 cut short the harvest period for Marglobe, which

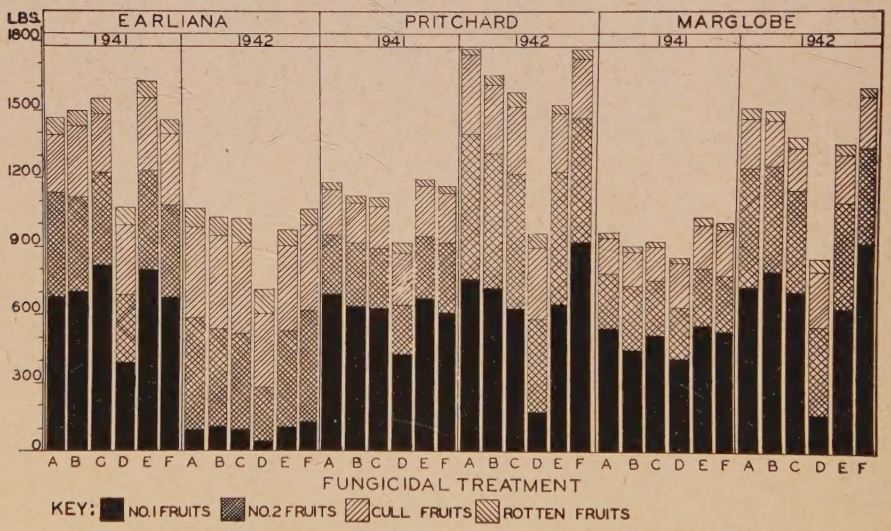

Figure 2.—Yield of fruit from 1/30-acre plots treated with different fungicides in 1941 and 1942. The fungicidal treatments are: (A) tribasic copper sulfate dust; (B) copper oxide dust; (C) copper oxide spray; (D) untreated check; (E) tribasic copper sulfate; and (F) Bordeaux spray.

probably accounted for the lower yield of marketable fruit than was obtained from Pritchard. All the fungicides used in the test gave a highly significant increase in yield of marketable fruit over the untreated check on all three varieties. On Earliana no one fungicide was superior to another but on Marglobe and Pritchard, Bordeaux gave higher yield of marketable fruit than did the other fungicides. On Pritchard the two dusts appeared to be superior to the same two fungicides (copper oxide and tribasic copper sulfate) when applied as sprays, the difference being significant at the 5 percent level. There was no difference in yield between the dusts and sprays on Earliana and Marglobe.

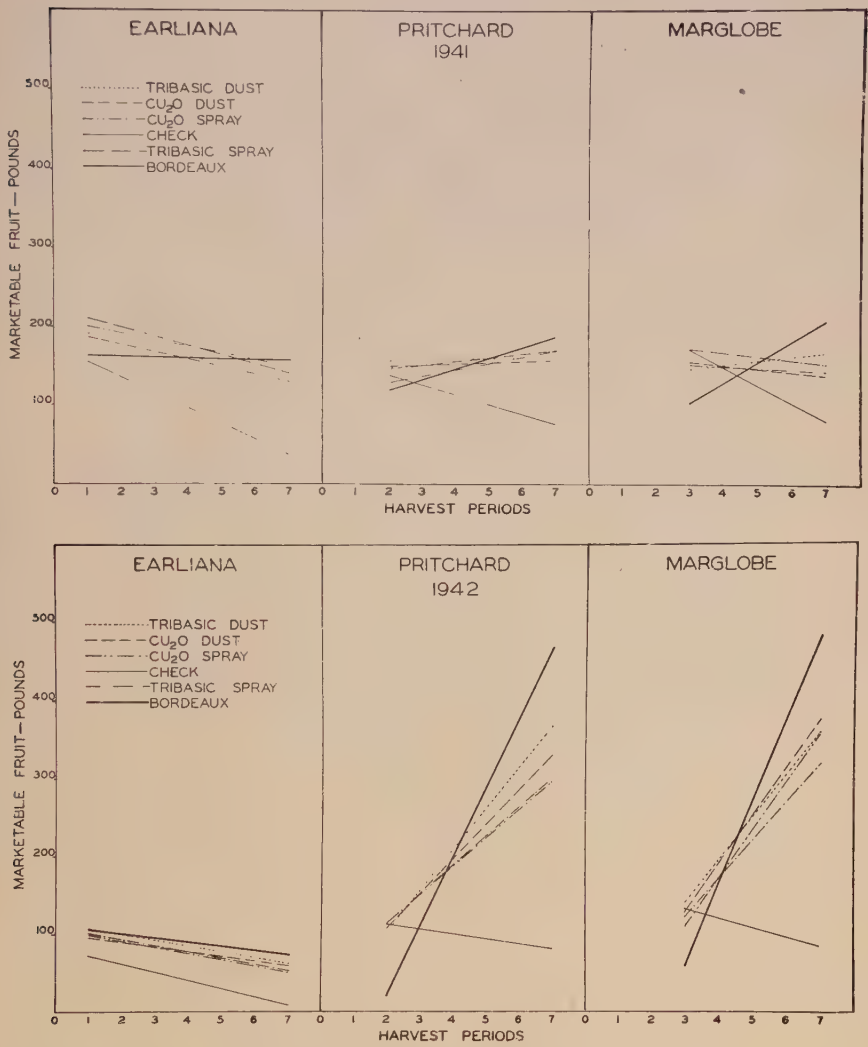

Figure 3.—Regression of yield of marketable fruit on harvest period (pickings).

The tendency for the pickings from the plots receiving fungicidal applications to be smaller than those from the untreated plot during the early part of the season and larger during the latter part of the season, as was noted in 1941, was also apparent in 1942; but the rapid falling off of yields from the untreated plots near the end of the season makes it difficult to distinguish between what might be a delay in ripening on the treated plants from the increased yields due

Table 4.—Yield of tomatoes in 1942 from plots of approximately 1/30 acre

Treatment	Harvest dates	Earliana				Pritchard				Marglobe			
		No. 1	No. 2	Culls	Rots	No. 1	No. 2	Culls	Rots	No. 1	No. 2	Culls	Rots
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Tribasic dust	7/27–8/5	3.0	3.3	2.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/6–8/15	17.5	48.0	37.0	22.3	4.8	4.0	2.3	1.5	0.0	0.0	0.0	0.0
	8/16–8/25	31.5	151.3	96.3	24.5	33.8	58.0	11.5	23.1	27.3	36.7	8.1	5.0
	8/26–9/4	15.0	229.5	168.0	25.0	130.3	180.8	22.5	12.0	78.3	141.2	18.3	7.5
	9/5–9/14	21.3	42.3	51.3	4.8	246.8	138.0	48.0	8.3	162.0	97.2	21.2	6.2
	9/15–9/24	1.3	5.5	13.8	4.0	266.0	192.5	134.5	11.8	337.4	169.7	74.8	17.9
	9/25	5.0	7.3	36.8	4.8	83.8	61.8	121.5	2.3	118.3	74.8	102.3	3.1
Total		94.6	487.2	405.2	86.9	765.5	635.1	340.3	38.2	723.3	519.6	224.7	39.7
Copper oxide dust	7/27–8/5	2.3	0.3	3.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/6–8/15	19.5	50.0	42.8	32.3	2.8	6.0	3.0	2.5	0.0	0.0	0.0	0.0
	8/16–8/25	28.0	126.0	73.0	25.8	40.8	63.3	14.3	4.3	21.6	40.8	11.0	5.2
	8/26–9/4	24.8	198.5	172.5	17.8	143.8	161.3	23.3	11.3	86.2	101.0	23.3	6.0
	9/5–9/14	23.0	43.0	62.8	7.0	224.8	121.8	47.5	6.0	172.0	92.7	22.3	6.2
	9/15–9/24	2.3	5.5	21.5	3.8	236.0	191.8	103.8	14.5	382.3	157.5	62.1	14.4
	9/25	3.3	11.3	29.0	3.5	72.8	46.3	104.8	3.3	124.5	73.5	83.9	4.0
Total		103.2	434.6	404.6	91.0	721.0	590.5	296.7	41.9	786.6	465.5	202.6	35.8
Copper oxide spray	7/27–8/5	3.5	5.0	1.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/6–8/15	26.0	48.5	37.8	27.5	7.5	5.0	3.0	2.0	0.0	0.0	0.0	0.0
	8/16–8/25	24.3	144.3	88.8	32.3	35.3	70.5	19.5	10.0	25.0	35.4	7.9	6.3
	8/26–9/4	14.8	166.8	169.8	31.8	119.8	182.3	29.5	19.0	62.7	107.5	24.0	11.2
	9/5–9/14	19.0	46.3	62.0	8.0	179.3	129.0	39.5	10.8	138.5	95.4	18.1	6.7
	9/15–9/24	2.3	3.5	14.3	3.0	237.5	167.0	88.3	15.5	344.9	120.6	52.5	14.8
	9/25	3.5	7.5	29.0	3.0	47.5	42.5	108.5	4.5	136.0	81.9	80.8	5.0
Total		93.4	421.9	403.2	106.6	626.9	596.3	288.3	61.8	707.1	440.8	183.8	44.0
Check	7/27–8/5	0.0	1.3	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/6–8/15	19.8	54.8	42.8	24.8	9.0	13.5	2.8	3.5	0.0	0.0	0.0	0.0
	8/16–8/25	21.8	133.0	114.3	48.8	35.8	81.8	35.3	10.5	21.2	52.7	14.1	10.9
	8/26–9/4	0.3	34.8	140.8	31.0	47.5	179.3	95.3	29.3	24.9	152.7	62.5	19.0
	9/5–9/14	2.8	8.8	25.8	3.0	35.5	66.5	65.3	7.8	46.3	67.4	37.6	6.0
	9/15–9/24	0.0	0.0	0.0	0.0	33.8	47.8	84.0	11.5	65.8	84.2	96.1	12.5
	9/25	0.0	0.0	0.0	0.0	11.8	14.8	38.5	2.3	5.7	19.8	39.8	2.4
Total		44.7	232.7	324.0	108.1	173.4	403.7	321.2	64.9	163.9	376.8	250.1	50.8
Tribasic spray	7/27–8/5	0.3	1.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/6–8/15	21.3	52.8	29.8	22.3	5.0	6.3	1.0	1.5	0.0	0.0	0.0	0.0
	8/16–8/25	43.5	156.8	95.5	20.5	51.5	55.8	9.0	3.0	18.3	26.3	9.2	4.0
	8/26–9/4	14.0	152.0	152.0	21.3	133.5	196.3	24.3	11.5	80.6	132.1	26.9	9.0
	9/5–9/14	19.8	51.0	57.8	4.8	155.5	128.3	50.5	6.8	119.2	90.5	25.8	5.8
	9/15–9/24	0.5	4.5	15.3	2.3	220.5	148.8	91.8	10.3	302.0	151.3	74.8	13.4
	9/25	3.8	7.8	22.0	2.8	73.8	53.3	83.5	2.5	109.6	60.6	80.7	2.1
Total		103.2	425.9	373.2	74.0	639.8	588.8	260.1	35.6	629.7	460.8	217.4	34.3
Bordeaux	7/27–8/5	2.3	1.3	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/6–8/15	20.8	40.0	28.5	18.3	4.5	5.3	0.8	2.3	0.0	0.0	0.0	0.0
	8/16–8/25	42.8	165.3	78.5	21.3	30.0	42.0	11.5	3.5	17.5	26.4	8.4	2.7
	8/26–9/4	22.3	204.8	137.8	22.0	115.5	125.5	24.0	13.3	61.3	79.4	14.5	7.6
	9/5–9/14	22.5	51.8	69.8	4.8	147.0	89.3	31.0	9.5	137.5	60.0	21.5	4.2
	9/15–9/24	6.0	4.3	19.8	3.5	376.0	170.3	74.3	16.8	472.7	152.6	66.1	21.0
	9/25	12.0	18.8	44.8	5.3	246.5	108.8	119.8	6.0	221.5	106.9	104.3	5.5
Total		128.7	486.3	379.7	75.7	919.5	541.2	261.4	51.4	910.5	425.3	214.8	41.0

to the lengthening of the bearing period. For this reason, the regression lines given in Figure 3 may be misleading. It will be readily seen, however, in examining the regression lines and in observing the yield data in Table 4 that the Pritchard and Marglobe plots sprayed with Bordeaux gave smaller yields in the early part of the season than did the untreated plots or the plots receiving either

Table 5.—Summary of analysis of variance on pounds of marketable fruit (No. 1 and No. 2)

Comparison	D/F	1941		1942	
		Sum of Squares	Mean Square	Sum of Squares	Mean Square
EARLIANA					
Blocks	3	968.63		1,364.35	
Treatments:					
(1) Trib. dust vs. $Cu_2 0$ dust	1	8.64	8.64	33.02	33.02
(2) $Cu_2 0$ spray vs. Trib. spray	1	0.17	0.17	3.01	3.01
(3) Dusts vs. sprays	1	405.08	405.08	48.89	48.89
(4) Others vs. Bordeaux	1	96.94	96.94	165.03	165.03
(5) Treatments vs. Check	1	7,047.01	7,047.01**	2,336.67	2,336.67**
Blocks X Treatment (Error A)	15	1,949.19	129.95	717.40	47.83
Pickings	6	206,767.02	34,461.17**	53,270.31	8,878.39**
Interactions:					
(1) T. dust vs. $Cu_2 0$ dust X Pickings	6	209.86	34.97	135.37	22.56
(2) $Cu_2 0$ S. vs. Trib. S. X Pickings	6	372.72	62.12	161.87	26.98
(3) Dusts vs. sprays X Pickings	6	240.26	40.07	932.72	155.45**
(4) Others vs. Bord. X Pickings	6	1,989.08	331.51**	255.60	42.60
(5) Treatment vs. Check X Pickings	6	11,893.49	1,982.25**	4,845.28	807.55**
Error B	108	8,536.43	79.04	4,538.00	42.02
Total	167	240,484.52		68,807.52	
PRITCHARD					
Blocks	3	677.41		1,193.45	
Treatments:					
(1) Trib. dust vs. $Cu_2 0$ dust	1	31.69	31.69	176.34	176.34
(2) $Cu_2 0$ spray vs. Trib. spray	1	54.19	54.19	1.03	1.03
(3) Dusts vs. sprays	1	7.03	7.03	698.76	698.76*
(4) Others vs. Bordeaux	1	1.20	1.20	960.50	960.50*
(5) Treatments vs. Check	1	2,641.17	2,641.17**	19,489.60	19,489.60**
Blocks X Treatment (Error A)	15	2,276.30	151.75	1,966.55	131.10
Pickings	5	167,573.95	34,061.84**	142,451.23	28,490.24**
Interactions:					
(1) T. dust vs. $Cu_2 0$ dust X Pickings	5	263.94	52.79	238.67	47.73
(2) $Cu_2 0$ S. vs. Trib. S. X Pickings	5	575.09	115.04	490.35	98.07
(3) Dusts vs. sprays X Pickings	5	544.84	108.98	1,484.80	296.96
(4) Others vs. Bord. X Pickings	5	2,728.63	545.73**	16,530.26	3,306.05**
(5) Treatment vs. Check X Pickings	5	4,546.68	909.34**	21,913.69	4,382.74**
Error B	90	11,452.04	127.24	25,982.00	288.69
Total	143	193,374.16		233,577.23	
MARGLOBE					
Blocks	3	1,050.49		2,406.49	
Treatments:					
(1) Trib. dust vs. $Cu_2 0$ dust	1	70.23	70.23	3.61	3.61
(2) $Cu_2 0$ spray vs. Trib. spray	1	70.23	70.23	78.40	78.40
(3) Dusts vs. sprays	1	31.24	31.24	819.20	819.20
(4) Others vs. Bordeaux	1	0.36	0.36	948.64	948.64*
(5) Treatments vs. Check	1	800.42	800.42	18,916.93	18,916.93**
Blocks X Treatment (Error A)	15	2,689.76	179.32	2,785.46	185.75
Pickings	4	75,594.47	18,898.62**	127,068.95	31,767.23**
Interactions:					
(1) T. dust vs. $Cu_2 0$ dust X Pickings	4	321.65	80.41	260.16	65.04
(2) $Cu_2 0$ S. vs. Trib. S. X Pickings	4	1,161.65	290.41	570.86	142.71
(3) Dusts vs. sprays X Pickings	4	197.51	49.38	681.93	170.48
(4) Others vs. Bord. X Pickings	4	5,120.34	1,280.09**	7,349.12	1,837.28**
(5) Treatment vs. Check X Pickings	4	2,518.08	629.52**	20,431.28	5,107.82**
Error B	72	12,447.50	172.88	8,560.30	118.89
Total	119	102,073.93		190,881.33	

* Values show significance at 5 percent level.
** Values show significance at 1 percent level.

of the other fungicides. The analysis of variance showed that the pickings from the Bordeaux plots were significantly different (1 percent level) from those from the plots treated with other fungicides (Table 5). There appeared to be no difference between copper oxide and tribasic copper sulfate in their effect on the yield of fruit at the different picking dates, except possibly on the Earliana variety.

The yields by grades calculated on a percentage basis are given in Table 2. The amount of No. 1 fruit from the untreated plot of Earliana was 6.3 percent; of Pritchard, 18.0 percent; and of Marglobe, 19.5 percent. Bordeaux increased the amount of the No. 1 fruit of Earliana to 12.0 percent; of Pritchard to 51.8 percent, and of Marglobe to 57.2 percent. The other fungicides also brought about a considerable increase in the proportion of No. 1 fruits, but the proportion was somewhat less than that for Bordeaux. A summary of the analysis of variance on the percentage of No. 1 fruits is given in Table 6. The average for all the fungicidal treatments was significantly higher (1 percent level) than that for the check on all three varieties. Bordeaux was significantly better than the other fungicides on Pritchard and Marglobe but not on Earliana.

Discussion

The observations made during 1941 and 1942 clearly indicate that the degree of control of tomato blight obtained by the application of fungicides is greatly influenced by the variety and by the weather. In 1941 the rainfall in the early part of the summer was abundant and the season was favorable for plant growth, but during the latter part of the summer, when the plants were bearing ripe fruits, the rainfall was very deficient. Thus, during the period when blight usually develops the season was dry and unfavorable for disease development, and under these conditions the extremely susceptible variety, Earliana, produced high yields and all the fungicides used in the test gave very satisfactory control of blight. On the other hand, in 1942 the rainfall was high throughout the season and the conditions were favorable for blight during the harvest period. Under these conditions the fungicides failed to give satisfactory protection on Earliana, although the treated plots gave significantly higher yields than the untreated ones. On Pritchard and Marglobe, however, the fungicides gave a large increase in yield of marketable fruits. Thus, gardeners who use fungicides on early varieties may be disappointed in the blight control obtained if the season is very favorable for disease development, whereas highly beneficial results may be obtained on late varieties under the same conditions.

In the tests reported, there was no outstanding difference in the efficiency of the different fungicides employed. During the dry season of 1941, Bordeaux spray appeared to give a lower percentage of No. 1 fruits than the other fungicides, but in the wet season of 1942 it was superior to the other fungicides in this respect. Also, Bordeaux gave slightly larger yields than the other materials in 1942. This indicates that the fungicidal value of Bordeaux is superior to that of copper oxide and tribasic copper sulfate. A disadvantage of using Bordeaux, however, is that it definitely delays the date of harvest. In other words the peak of the harvest from Bordeaux sprayed plants is later in the season than that from plants treated with the other forms of copper. In a wet season this delay should not affect the total yield, but in an average season the chances are that a delay in the harvest peak would result in a smaller total yield because of drouth in late season. The average rainfall for Southwest Virginia for August is 4.48 inches, while for September it is only 3.08 inches. Thus, a delay in maturing the crop

Table 6.—Summary of analysis of variance on percentage of No. 1 fruits

Comparison	D/F	1941		1942	
		Sum of Squares	Mean Square	Sum of Squares	Mean Square
EARLIANA					
Blocks	3	47.46		161.29	
Treatments:					
(1) Trib. dust vs. Cu_2O dust	1	.50	.50	2.64	2.64
(2) Cu_2O spray vs. Trib. spray	1	24.50	24.53	4.06	4.06
(3) Dusts vs. sprays	1	72.23	72.23*	.77	.77
(4) Others vs. Bordeaux	1	22.05	22.05	18.53	18.53
(5) Treatments vs. Check	1	468.07	468.07**	56.03	56.03**
Error	15	198.79	13.25	63.45	4.23
Total	23	833.63		306.77	
PRITCHARD					
Blocks	3	19.46		119.78	
Treatments:					
(1) Trib. dust vs. Cu_2O dust	1	4.50	4.50	.50	.50
(2) Cu_2O spray vs. Trib. spray	1	1.11	1.01	12.50	12.50
(3) Dusts vs. sprays	1	3.07	3.07	20.25	20.25
(4) Others vs. Bordeaux	1	90.32	90.32	296.45	296.45**
(5) Treatments vs. Check	1	255.21	255.21*	2349.67	2349.67**
Error	15	467.29	31.15	310.47	20.70
Total	23	840.96		3109.62	
MARGLOBE					
Blocks	3	978.79		194.79	
Treatments:					
(1) Trib. dust vs. Cu_2O dust	1	0.12	0.12	40.50	40.50
(2) Cu_2O spray vs. Trib. spray	1	10.13	10.13	32.00	32.00
(3) Dusts vs. sprays	1	6.26	6.26	9.00	9.00
(4) Others vs. Bordeaux	1	51.20	51.20	204.80	204.80*
(5) Treatments vs. Check	1	185.00	185.00*	3381.41	3381.41**
Error	15	359.46	23.96	357.46	23.81
Total	23	1590.96		4219.96	

* Values show significance at 5 percent level.
** Values show significance at 1 percent level.

Table 7.—Comparison of yields from plots receiving fungicidal applications and plots receiving no treatment

Treatment	Tons of fruit per acre*					
	1941			1942		
	Number 1	Number 2	Total	Number 1	Number 2	Total
Earliana:						
Treated	11.10	6.43	17.53	1.22	6.82	8.04
Check	5.79	4.43	10.22	.68	3.52	4.20
Increase	5.31	2.00	7.31	.54	3.30	3.84
Pritchard:						
Treated	9.82	4.14	13.96	11.12	8.92	20.04
Check	6.50	3.27	9.77	2.62	6.11	8.73
Increase	3.32	.87	4.19	8.50	2.81	11.31
Marglobe:						
Treated	7.97	3.71	11.68	11.36	6.99	18.35
Check	6.16	3.43	9.59	2.48	5.70	8.18
Increase	1.81	.28	2.09	8.88	1.29	10.17

* Per acre yields are calculated from the average of four 1/121-acre plots for the checks and from twenty similar plots for treatments; that is, all plots receiving fungicides were averaged together.

would in some years result in a lower yield due to extending the bearing period into the dryer season.

If the picking yields in Table 1 are examined closely, it will be seen that in 1942 for Pritchard and Marglobe about 25 percent of the total yield of marketable fruit from the plots sprayed with Bordeaux was obtained in the last 10-day period, while in the same period the average portion of the crop obtained from the plots treated with the other fungicides was 9.4 percent for Pritchard and 16.4 percent for Marglobe. This means that the yields from the Bordeaux plots were poorer than those from the plots receiving other fungicides up until the last harvest period. In 1942, as frequently happens in this area, the plants were killed by frost on September 27, but in order that the yield records would be complete all fruits remaining on the vines on this date were picked and graded as usual, disregarding color if the fruits were mature in size. If a green-fruit or partially ripe-fruit market had not been available, a considerable portion of the fruit from the Bordeaux sprayed plots would have been lost.

The advisability of using Bordeaux on tomatoes, if one of the other fungicides is available, would be questionable because of the tendency for Bordeaux to delay the date of harvest in all seasons and because of the risk of obtaining lower yields in dry seasons and the danger of losing the last portion of the crop from an early frost.

In 1942 copper oxide and tribasic copper sulfate applied as a dust gave a higher yield on Pritchard than the same materials applied as a spray. This result is contrary to the usual assumption that dusts are less effective than sprays. The better yields with dusts than sprays on Pritchard, however, indicates that dusts may be just as effective as sprays if equal coverage is obtained. In these tests the dust was carefully applied so as to obtain a thorough and uniform coverage of the foliage. As has been pointed out by McNew (12), it is probable that poor dusting equipment is responsible for dusts in general giving a less degree of control than sprays. It can also be added that the reason why some gardeners and tomato growers have not obtained satisfactory control of blight by fungicidal applications, be it dust or spray, is due to poor equipment and inexperience in applying fungicides.

Summary and Conclusions

The results of experiments on the control of tomato foliage diseases by the use of copper fungicides are reported. Five fungicides were tested on three varieties of tomatoes which differed in date of maturity. The varieties were Earliana (early), Pritchard (medium early), and Marglobe (late). The fungicides were copper oxide dust, copper oxide spray, tribasic copper sulfate dust, tribasic copper sulfate spray, and Bordeaux mixture applied as a spray.

In 1941, which was a dry season during August and September, Earliana and Pritchard gave excellent yields and responded very favorably to the fungicidal applications. The yield of Marglobe, however, was very much reduced by the drought and the fungicidal applications did not significantly increase the yield over that of the untreated plots. No one fungicide proved to be superior to the others.

In 1942 the rainfall during the growing season was much greater than that of the previous year. Under these conditions the Earliana variety proved to be extremely susceptible to "blight" and the yield of marketable fruit produced by it was very low. All the fungicides gave significant increases in yield over the untreated plots, but in general the degree of disease control obtained on Earliana

was unsatisfactory. The yields of the Pritchard and Marglobe varieties were much higher than in 1941 and all the fungicides gave a large increase in the amount of marketable fruit. Bordeaux was significantly better (5 percent level) than the other fungicides in increasing the yield of marketable fruit.

Bordeaux in every instance delayed the maturity of the fruit; that is, the peak of the harvest of fruit was later in the season than that from plants treated with other fungicides, or that from untreated plants. This delay was most pronounced in case of the later varieties and was only slightly noticeable on Earliana in 1942.

The application of fungicides gave a marked increase in the percentage of No. 1 fruits each season. The increase in 1941, however, averaged only about 10 percent for the three varieties; whereas in the rainy season of 1942, it was about 30 percent for Marglobe, 25 percent for Pritchard, and only 3 to 5 percent for Earliana.

It is concluded (1) that the yield and quality of marketable fruit on tomatoes in Southwest Virginia can be greatly increased by 4 to 6 applications of a copper fungicide; (2) that copper oxide and tribasic copper sulfate applied either as a dust or as a spray give a marked degree of control of tomato leaf blight but are not as efficient as Bordeaux spray in a rainy season; (3) that Bordeaux delays the date of the harvest peak of fruit to a much greater extent than either copper oxide or tribasic copper sulfate; and (4) that the control of blight is more difficult on early maturing varieties, like Earliana, in a season favorable for disease development than on later maturing varieties.

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